NEW APPROACH FOR PREDICTION THE DC BREAKDOWN VOLTAGE USING FUZZY LOGIC CONTROLLER

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Abstract
High voltage device design needs predicting the withstanding voltage to assay conditions as pulses, surges and the DC voltage. There is a great designer needed to have reliable design requirements and well-defined simulation procedure for the development of the apparatus. In this paper, Fuzzy Logic (FL) method is used to model breakdown voltage, based on experimental data generated in the laboratory. Different models are proposed with different membership functions for the FL under both DC voltage conditions. The purpose of this article is to investigate the discharge phenomenon for an air gap-point plan at with insulation barrier between themselves. Obtained results are encouraging. Proving that fuzzy logic is a powerful tool that can be used in predicting the properties of the barrier.

Keywords: Fuzzy logic Controller, Number of partitions, Breakdown voltage, Barrier, Point-Plane.

1. INTRODUCTION

Barriers are used in largely several high-voltage devices. It has been known that the dielectric of the strength of the long gap is significantly increased by inserting an insulating barrier. Each insulating structure gives particular discharge phenomenon [1-4].

Knowing the ionization state and the spread of electric discharge are of great importance to fully understand the mechanism behind the breakdown [5-9].

The insertion of the barrier near the sharp electrode has a great influence on the dielectric strength [10-15].

The effectiveness of the barrier depends on the geometry and position and the physical nature of the barrier. The survey has been simulated and conducted experimentally and to study the barrier breakdown phenomenon [16-22].

As a result, three materials have the same effect on the barrier. The breakdown voltage varies with the size of the barrier, and the maximum flashover voltages is observed where the barrier is positioned at the closest point the electrode [23-31].

The small size of barrier becomes effective in very small air spaces.

Based experimental results, a Sugeno fuzzy logic system is modelled to predict DC breakdown voltage, in terms of the relative position of the barrier, the hole, the width of the barrier, and the nature of the barrier. In fact, the breakdown phenomenon depends on this variable [32-34].

In this paper, details of a proposed method for the prediction of electric discharge in air using fuzzy logic.

The use of the fuzzy logic technique allows us to have a numerical system that can predict the electric discharge using the fuzzy reasoning.

The difficulty of obtaining a mathematical model which can reflects the evolution of the electric discharge in the field of high voltage has obliged several researchers to introduce different analysis and methods to study such a subject [35-36]. In this work, to use the fuzzy logic technique based on experimental data to predict the electrical discharge in a point-to-plane system.

The used database are collected from tests conducted at the high-voltage laboratory of the University of Biskra.

2. EXPERIMENTAL SETUP

The experimental set-up consists of a high-voltage test transformer 100kV/5kVA/ 50Hz, a capacitive voltage divider. Fig 1 and Fig 2 (the experiences have been performed in the laboratory of high voltage University of Biskra).

Shows the arrangement of electrodes and insulating barrier it contains a point–plane electrode arrangement mounted vertical. The HV electrodes consist a steel needlepoint on copper of conical in shape 30°. The grounded plan electrode is a circular steel plate of 30 cm long, 2.8 cm diameter.
The plexiglas barriers (\(\varepsilon_r=3.3\)), the second type of barrier used is bakelite (\(\varepsilon_r=5.82\)), and The third type of barrier used is Glass barriers (\(\varepsilon_r=6\)), are squares of different widths (5 cm, 10 cm, 15 cm) and different holes (4mm, 8mm and 12mm) and its thicknesses is 1mm, an aluminium plan grounded. To change the positions for several barriers, carriers Bakelite are used.

The barrier is mounted vertically between the electrodes Fig 2. Its surfaces are checked after each breakdown. The position of the barrier is defined by the ratio \(\left(\frac{a}{d}\right)\), where \(a\) is the point–barrier distance and \(d\) the point–plan electrode gap.

### 3. DESIGN OF A FUZZY SYSTEM FOR PREDICTION

In this paper a hierarchical structure of Sugeno model was adopted to predict the breakdown voltage in terms of the relative position \(R\) and the Width of the barrier, for two values of relative permittivity and the hole Fig. 3 (Fuzzy logic system).

Each input variable (R or W) is quantified into their fuzzy subsets: small S, medium M and large L.

Memberships of these subsets have triangular shapes (Fig. 4 and 5).

| Tab.1. Rule base of the fuzzy systems FLS\(_k\) |
|---|---|---|---|
| (mm) | S | M | L |
| S | \(V_{11}\) | \(V_{12}\) | \(V_{13}\) |
| M | \(V_{21}\) | \(V_{22}\) | \(V_{23}\) |
| L | \(V_{31}\) | \(V_{32}\) | \(V_{33}\) |

Where: \(V_{ij}\) are values of the output of the fuzzy rules, for \(\varepsilon_r = \varepsilon_k\) and \(H = H_j\).

The expression of the output of the value fuzzy system is

\[
V_c(kf) = \frac{\sum \mu_j(R)\gamma_j(W)W_f(kf)}{\sum \mu_j(R)\gamma_j(W)}
\]  

(1)

Membership function as a function of distance:

\[
\mu_1(R) = \max\left(\frac{3-R}{2} , 0\right) \rightarrow e^{-\frac{R-1}{\sigma}^2}
\]

\[
\mu_2(R) = \max\left[ \min\left(\frac{R-1}{2}, \frac{3-R}{2}\right) , 0\right] \rightarrow e^{-\frac{R-3}{\sigma}^2}
\]

\[
\mu_3(R) = \max\left(\frac{R-3}{2}, 0\right) \rightarrow e^{-\frac{R-5}{\sigma}^2}
\]

(2)

Membership function as a function of Width...
The relative permittivity $\varepsilon_r$ has been quantified into two fuzzy values (3.3 and 6).
The hole H has been quantified into two values (4mm and 12 mm).
Their membership function are presented in Fig 6 and 7).

Fig. 6. Membership function of the nature of the barrier material

Rule of inferences of the fuzzy system FLC control:
FLC, $1 \leq i \leq h$
IF(R and S) and (W and M) so $V_C = (R=1, W=15) \Rightarrow S$
IF(R and S) and (W and H) so $V_C = (R=1, W=25) \Rightarrow S$
IF(R and S) and (W and S) so $V_C = (R=3, W=5) \Rightarrow M$
IF(R and S) and (W and S) so $V_C = (R=3, W=15) \Rightarrow M$
IF(R and S) and (W and t S) so $V_C = (R=3, W=5) \Rightarrow M$
IF(R and S) and (W and S) so $V_C = (R=5, W=25) \Rightarrow H$
IF(R and S) and (W and S) so $V_C = (R=5, W=15) \Rightarrow H$
The whole fuzzy system can be presented by Fig 8.

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>S</th>
<th>H</th>
<th>M</th>
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<tr>
<td>S</td>
<td>$V_{CM}(1.5)$</td>
<td>$V_{CM}(1.15)$</td>
<td>$V_{CM}(1.25)$</td>
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<tr>
<td>H</td>
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<td>$V_{CM}(3.15)$</td>
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<tr>
<td>M</td>
<td>$V_{CM}(2.5)$</td>
<td>$V_{CM}(3.15)$</td>
<td>$V_{CM}(3.25)$</td>
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Fuzzy Controller (FLC)
4. RESULTS AND DISCUSSION

4.1 Prediction of the permittivity relative of the barrier Bakelite $\varepsilon_r$=5.82 and the hole H=8mm

Figures (9, 10, 11 and 12) present results of the training phase for different couple of values of H and $\varepsilon_r$ ($H, \varepsilon_r$) = (12, 6), (4, 6), (12, 3.3), (4, 3.3).

The validation phase consists in the prediction of the DC breakdown voltage for $\varepsilon_r$ =5.82 and H=04 mm, 8 and 12 mm and for $\varepsilon_r$ =3.3 and 6 for H=8mm obtained results are compared to experimental ones in figures (13 - 17).

Observing these figures, it is clear that the obtained prediction values of the DC breakdown voltage are close to experimental ones.

4.2 Influence of the permittivity relative of the barrier on the breakdown voltage

Figures (10, 12, and 16) shows the experimental and predicted breakdown voltage as a function of the relative position of the barrier values of the barrier for different width (5cm, 10 cm, 15 cm, 20 cm and 25 cm) of the barrier. The hole in the barrier is (4 mm). Different permittivity is (3.3, 5.82 and 6). Different distances between the point and the barrier (1cm to 5 cm) were studied.

The insertion of the barrier has a significant influence on the breakdown voltage. This means that the founded model by the fuzzy logic method is perfect.

4.3 Influence of the hole in the barrier on the breakdown voltage

In this test, Figures (9, 10, and 13) holes in the middle of the barrier varies (4mm,8mm and 12mm) the relative position of the barrier values for (1cm to 5 cm), different width (5cm 10cm, 15cm, 20cm, and 25cm), the permittivity of the barrier is ($\varepsilon_r$ = 6).

Figures (14, 15, and 16) holes in the middle of the barrier varies (4mm,8mm and 12mm) the relative position of the barrier values for (1cm to 5 cm) different width (5cm, 10cm, 15cm, 20cm, and 25cm), the permittivity of the barrier is ($\varepsilon_r$ = 5.82 ).

In reviewing figures, we observe that the decrease of the breakdown voltage with the increase of the holes in middle of the barrier. This result could be interpreted by the fact that the electric charge that passes through the hole is low. When a diameter of hole is greater, a large part of the charging space passes through the hole as well. This can be interpreted by the fact that increasing the diameter of the hole.
5. Conclusion

In this paper, a new approach based on an expert system of fuzzy logic modelling has been proposed to predict the behaviour point-plan with different barrier used in high voltage. It is to value of the breakdown of the point to plane interval is close to experimental results. In this study the breakdown mechanism has been investigated with help of point-plan with barrier both experimentally and by simulation with MATLAB environment. In this study considering no change of physical condition like temperature and pressure. The effect of breakdown voltage on different insulation like (glass, bakelite and plexiglas), has also been studied. To observe the effect on insulation due to breakdown mechanism. The optimized maximum breakdown voltage is reduced as the holes on the barriers are made wider to a point where the barrier effect is not felt. The width of the hole depends on the length of the space. With a very small air gap a small hole on the stopping surface leads to a significant reduction in the breakdown voltage. It also depends on the location of the hole. If it is located at the central point of the barrier, it eliminates all the beneficial effect of the barrier.

For practical purposes, porous barriers are not recommended for voltage optimization. Sugeno models and adaptive fuzzy logic are some of the recent trends. These also provide better estimation and better tuning techniques. Has been very effective in predicting the breakdown voltage under DC conditions. As cannot claim about the optimality of the system, so it is better to model with all the available and algorithm choose the best estimate, gives very encouraging results. The simulation and experimental results confirmed that using a dielectric barrier in high voltage system configuration significantly increases the breakdown voltage.

6. REFERENCES


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